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Keller, Jann T.; Kuper, Gerard H.; Mulder, Machiel

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ORIGINAL ARTICLE

Competition under revenue-cap regulation with efficiency benchmarking: tariff related incentives for gas transmission system operators in merged markets

Jann T. Keller[1,2] · **Gerard H. Kuper**[1] · **Machiel Mulder**[1]

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Abstract
In Europe, gas market mergers aim at reducing restrictions on gas wholesale markets. Market mergers also allow network users to book transport capacity at different gas transmission system operators (TSOs), which may give rise to inter-TSO competition. Our theoretical analysis reveals the incentive for TSOs, operating under a revenue-cap regulation in merged markets, to charge lower tariffs at borders where different TSOs offer capacity, compared to borders where only one TSO offers capacity. This incentive does not directly result from revenue-cap regulation but is due to efficiency benchmarking. We test this hypothesis by applying a panel data analysis to tariffs charged at German border points between 2015 and 2018. In line with our hypothesis, we find lower tariffs at those border points where network users have a choice between different TSOs. An additional sensitivity analysis differentiating between transit and meshed networks confirms this result. We conclude that German TSOs, operating in merged markets and under a revenue-cap regime with efficiency benchmarking, compete for demand at borders at which different TSOs offer capacity.

Keywords Gas market · Tariff regulation · Competition · Market merger

JEL Classification D47 · K23 · L51 · L95 · L98 · Q48

The views expressed in this paper are those of the authors and do not necessarily reflect those of GTG, and do not constitute any obligation on GTG.

✉ Jann T. Keller
j.keller@rug.nl

[1] Faculty of Economics and Business, University of Groningen, Groningen, The Netherlands

[2] Gastransport Nord GmbH (GTG), Oldenburg, Germany

1 Introduction

According to economic theory, the absence of effective competition requires regulation of natural monopolies. Such monopolists are often infrastructure operators. In gas markets, transmission and distribution networks are natural monopolies, and hence they are regulated. Transmissions networks, operated by transmissions system operators (hereafter: TSOs), connect all major players and infrastructures of gas markets. Therefore, they are the backbone of gas markets that facilitate wholesale markets.[1] In Europe, there are gas market areas organised as so-called *entry-exit systems*, which also allows for cross-border trade. To reduce barriers to trade, and to increase wholesale market liquidity and competition, several European gas markets have already merged with more mergers to be expected. Market mergers facilitate market integration. Barriers, like tariffs, between markets disappear, so that single markets are joined to become one market, resulting in a single price on the wholesale market for gas (ACER and CEER 2015).

Besides the impact on wholesale markets, market mergers can also have an impact on the behaviour of gas TSOs. If, after a merger of market areas, two TSOs operating in the same market area are both connected to another adjacent market area, network users obtain transport alternatives; network users must choose between different TSOs (Keller et al. 2019). Thus, market mergers may imply inter-TSO competition. However, such a competition may only be possible if the demand side makes its choices efficiently. Keller et al. (2019) analysed the efficiency of network users' booking capacity and found their booking behaviour is sensitive to differences tariffs.

Price-sensitive booking behaviour is a prerequisite for inter-TSO competition. However, it is not a sufficient condition for inter-TSO competition. Since TSOs are regulated entities, the possibilities, and the incentives to engage in tariff competition, are determined by the regulatory regime applied. Therefore, it is necessary to analyse how TSOs in merged market areas set tariffs assuming efficient booking behaviour on the demand side, and considering the regulatory regime applied.

The literature describes several regulatory regimes applied to energy networks, which differ in the incentive power, and the level of profits allowed (Arcos-Vargas et al. 2017). Armstrong and Sappington (2006) examine how to introduce competition in regulated industries and find that an optimal liberalisation process highly depends on the institutional setting. In the case of the liberalisation of the British gas market, they show that allowing for competition in regulated industries often refers to activities such as production and supply of utilities, and not directly to infrastructure competition. Vogelsang (2002) assesses the competitive role of price-cap regulation and horizontal competition and concludes that price-caps allow for *regulation cum competition* given the flexibility they offer in setting prices for regulated output of a firm. However, the presence of (potential) competitors is required to introduce competition to a monopolist, which requires a contestable market and free market

[1] A wholesale market is the virtual place, where producers, traders, and larger retailers meet to buy and sell gas.

entry (Baumol 1982). Cave (2004, 2014) examines potential competition between an integrated incumbent owning telecommunication networks and new entrants. Laffont and Tirole (1996) claim a duplication of a network, noting that this is associated with high costs, may be justified as it may allow for competition. Studies and research intending to contribute explicitly to the future of tariff regulation in European gas markets do not take into account the role of market mergers with regard to the potential for inter-TSO competition on tariffs (Cervigni et al. 2019; EY and REKK 2018; Hecking 2015).

Our paper extends the literature on (de-)regulation of natural monopolists. Our focus is on the impact of market mergers on inter-TSO competition on tariffs. We contribute to the future of tariff regulation in European gas markets, but unlike other work the potential competition arises from merging markets with regulated monopolists and does not arise from unregulated new entrants into market.

This paper investigates tariff related incentives for TSOs that are regulated by a revenue-cap regime, which is the most common regulatory regime applied in European gas markets. In that case, TSOs may face competition because of market mergers. The first step in the investigation is the theoretical analysis of incentives for TSOs setting their tariffs considering market mergers. Next, it explores empirically whether regulated TSOs in Germany, who operate under a revenue-cap regulation and have experienced several market mergers, consider the presence of other TSOs in setting their tariffs.

According to theory, TSOs operating under revenue-cap regulation have an incentive to change tariffs to maximise profits. However, the incentive is not based on capping the maximum revenues but is due to efficiency benchmarking. The result of efficiency benchmarking, i.e. the efficiency score, is influenced by a TSO's level of capacity bookings.[2] As the efficiency score is considered by the regulator determining the allowed revenues, ultimately the level of capacity bookings impacts the TSO's revenues and profits. To obtain higher capacity bookings, a TSO has the incentive to charge lower tariffs. In an unmerged market, TSOs compete by reducing their costs per unit of output compared to their peer group. In a merged market, TSOs have an additional incentive as they also compete directly for the same demand at borders where more than one TSO offers capacity. Therefore, we expect lower tariffs at network points at borders where different TSOs offer capacity compared to borders where only one TSO offers capacity.

We test this hypothesis by applying a panel data analysis to tariffs charged between 2015 and 2018 at German border points by German TSOs that operate under a revenue-cap regulation with efficiency benchmarking. In line with our hypothesis, we find that the tariffs are up to 52% lower in case more than one TSO offers capacity at a border. An additional sensitivity analysis shows that this result is robust to a differentiation between transit and meshed networks. Hence, we conclude that German TSOs, operating in merged markets, and under a revenue-cap regime with efficiency benchmarking, have an incentive to reduce tariffs at competitive

[2] The efficiency score is derived from a benchmark analysis, which compares a ratio of TSO's output (i.e. capacity bookings) with input (costs) within a peer group.

network points, where they compete for demand. Our empirical analysis confirms TSO act accordingly.

Following this introduction, the paper describes in Sect. 2 how European gas markets are designed, how transmission networks are commercially operated, and how market mergers affect gas markets and market players and ends with describing the principles of tariff regulation. Section 3 continues with the theoretical framework analysing tariff related incentives for TSOs under a revenue-cap regulation also considering market mergers. In Sect. 4, we present our empirical model, the data used to test our hypothesis, and the results obtained. Section 5 concludes with summarising the main results and discussing the implications for further research and regulation.

2 Background

2.1 TSOs, network points, and market mergers

A TSO offers transmission services using a gas pipeline network. Transmission in this context refers to the transport of gas through a mainly high-pressure infrastructure that is not aimed at a direct local distribution, and does not include other activities, like production and storage, than gas transport. A TSO offers the use of the network by offering transport capacity to the market. Such capacity is demanded by so-called *network users* being, for example gas traders or suppliers (European Parliament and Council of the European Union 2009a).

Capacity that is offered at network points can be referred to as the right of a network user to inject or withdraw gas. Injection and withdrawal of gas within a TSO's network are independent from each other. The so-called *entry-exit system* allows a network user to inject (entry) gas at any point of the network, and to withdraw (exit) gas at any other point of the same network. The transport is the sole responsibility of the network operator. A TSO network, therefore, may also be referred to as an entry-exit system or a market area. As entry capacity and exit capacity are independent from each other, there are no predefined routes for gas transport within a market area. This is also reflected in tariffs charged for capacity bookings. For example, the same tariff is charged for capacity available at a certain exit point, regardless of the geographical distance from the corresponding entry point.[3] Therefore, tariffs may be deemed not to fully reflect costs. Gas injected into a TSO network may also be withdrawn virtually. Virtual injection and withdrawal mean that gas that is traded at wholesale markets stays in the pipelines, however the ownership of the commodity changes. As for tariffs this means that if gas is purchased at the wholesale market, and withdrawn at a physical network point, it is not known into which network point

[3] Nevertheless, some TSOs in practice determine tariffs considering geographical distance. This is done, for example, by using the so-called *capacity-weighted distance* approach (European Commission 2017b). However, distance is only considered in determining the tariff applicable at a certain network point without considering the actual distance the gas is flown.

the gas was originally injected, and hence the physical route of gas is unknown. Hence, an entry-exit system allows for trade in wholesale markets but is associated with capacity tariffs not fully reflecting costs.

There are two categories of network points: *Interconnection points* (hereafter: IPs) connect two market areas (European Commission 2017a). This means that IPs connect the network of two adjacent TSOs in different market areas. In practice, these IPs are usually located at the border between countries allowing for cross-border trades and flows. If a country has more than one market area, IPs also exists within a country. All other network points within a country are referred to as domestic points. These include, for instance, production sites, storage facilities, industrial customers, and networks for the purpose of local distribution.

The introduction of the entry-exit system allowed gas wholesale markets to evolve efficiently (Vazquez et al. 2012). To improve the functioning of these wholesale markets, that is increase liquidity and competition among trading companies, market areas are merged. As a result of adjacent markets merging, the commercial barriers between the formerly separate markets disappear, and their wholesale markets become one with a single price for gas (ACER and CEER 2015). Such market mergers have taken place, for example within France and Germany, and even between countries, for example between Belgium and Luxembourg. Future mergers are expected not at least because regulatory authorities aim at further improving the functioning of wholesale markets (ACER and CEER 2015).[4]

To flow gas to an adjacent market area, network users need to book capacity at IPs located at the border separating the adjacent markets. The tariffs paid for such capacity bookings represent transportation costs. As each market area has its own wholesale market for gas, it can be expected that without any other restrictions the difference between wholesale prices for gas does not exceed the tariffs to be paid for transport capacity, i.e. the transportation costs. If these two adjacent markets merge, there is no border between them anymore. If the border disappears also the need to book capacity connecting the former markets disappears. Obviously, the border and the capacity disappear only in a commercial sense, i.e. in terms of gas trading. As a market merger does not impact the physical networks, the network points still exist, and are still needed to allow for physical gas flows between the networks via these points. However, as the former markets now belong to the same market area, network users no longer must book these capacities. The reason is that also the new market area is organised as an entry-exit system, which allows network users to inject and withdraw gas independently from each other, and independently from the underlying networks and TSOs. As for a merged market, network users may inject gas into one TSO's network, and withdraw it from another TSO's network, while the TSOs are responsible to manage these flows.

Although market mergers are pursued to improve the functioning of gas wholesale markets, they also affect the TSOs of the market areas merging. Merging two

[4] One of the next market mergers takes place in Germany. By October 2021, the current market areas *GASPOOL* and *NetConnect Germany* shall be merged to become *Trading Hub Europe*. See http://www.marktgebietszusammenlegung.de/en.

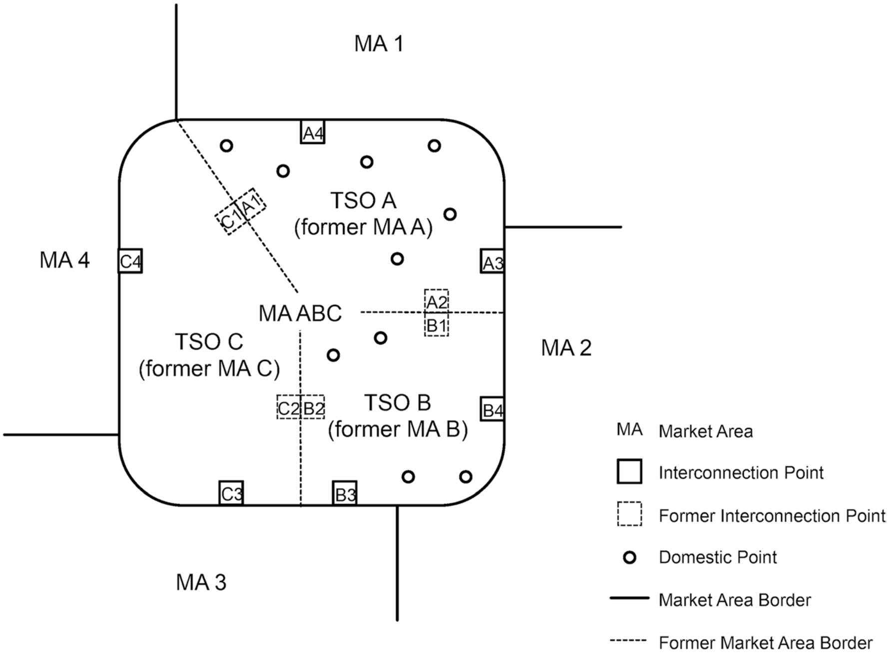

Fig. 1 Stylised commercial relationship of TSOs, borders of market areas, and network points

market areas, having one TSO each, usually leads to a new market area having two TSOs.[5] This creates transport alternatives to network users in case the two TSOs have an IP at a border to a third market area (Keller et al. 2019). This is illustrated in Fig. 1. Suppose initially there are three market areas, namely MA A, MA B, and MA C, each operated by its own TSO, namely TSO A, TSO B, and TSO C. Each of these market areas, organised as an entry-exit system, has its own gas wholesale market. All three TSOs offer capacity at IPs. TSO A and TSO B also offer capacity at domestic points, whereas TSO C is a transit TSO not having domestic network points.[6] Each TSO also has IPs connecting its network, and hence the market area's wholesale market, to the other networks. Now assume the market areas A, B, and C merge to become a single market area denoted as MA ABC. As mentioned before, a merger means that borders commercially disappear. Referring to the figure, this means IPs A1, A2, B1, B2, C1, and C2 are not subject to capacity bookings anymore, as all three TSOs now belong to the same market area. Gas, for example injected into TSO B's network may be withdrawn at a domestic point of TSO A

[5] It is conceivable that TSOs in the new, merged market area belong to the same parent company, which may affect their competitive behavior. We assume that this is not the case, and the TSOs are separate companies, which is generally the case.

[6] Note that the focus is on commercial aspects. Hence, physical pipelines are not relevant because the market areas are designed as entry-exit systems, and therefore, omitted in the figure.

without any additional capacity booking in between, since the commercial border between market areas A and B no longer exists. Hence, there are also lower transportation costs. From a network users' point of view, this is like as if there was only one TSO instead of two. Because the commercial borders disappear wholesale markets are no longer separated, hence by merging the market areas also the wholesale markets merge.

As a result of market mergers also another, not directly intended, effect can be observed. This refers to potential inter-TSO competition which is the focus of this paper. Referring to the example in Fig. 1, MA 2 and MA 3 are each connected to two TSOs. Assume that in wholesale market MA ABC prices are significantly lower than in wholesale market of MA 3, i.e. the price difference exceeds the transportation costs. This is a price signal that allows for arbitrage. Since TSO B and TSO C are both connected to MA 3, and after the merger both belong to MA ABC, network users can choose between capacity of TSO B, and that of TSO C to make use of the arbitrage opportunity. Noting that capacity is highly standardised, a network user is supposed to choose from the alternatives the one which is associated with least costs; this has been demonstrated by Keller et at. (2019). Since this effect results from market mergers, market mergers may allow for inter-TSO competition.

Unlike IPs at the borders, where from a network users' point of view substitutes may arise due to a merger, domestic points are usually connected to just one transmission network. Most domestic points refer to end customers. These are characterised by a relative inelastic demand; hence, they can be viewed as captive demand. For households, gas is usually used for cooking and heating. Once a cooking facility or heating system has been installed, the household is locked-in into this technology. Although, for example additional insulation and changes in behaviour may lead to a lower demand for gas, there are still high switching costs related to a full fuel switch. The same applies to industrial customers, who may have a limited ability to switch fuels.

2.2 Tariff determination

In general, TSOs are regulated as they are natural monopolists facing no effective competition. Regulation of European TSOs mainly consists of network access regulation and tariff regulation supported by ownership unbundling and transparency provisions (European Commission 2017a, b; European Parliament and Council of the European Union 2009a, b).

Tariff regulation determines how much a regulated TSO is entitled to earn from network charges paid by network users. In principle, determining this maximum, the so-called *allowed revenues,* includes consideration of the costs of realised investments as well as the costs to operate and maintain the infrastructure. In addition, an appropriate return on capital ensures a firm can finance the investments. In the literature, there are different regulatory regimes, which are either cost-based (like cost-plus and rate-of-return regulation) or incentive-based (like price-cap, revenue-cap, and yardstick regulation) (Arcos-Vargas et al. 2017). The differences refer to how the allowed revenues are related to the firm's costs, which leads to different incentives for the regulated firm (see for example Braeutigam and Panzar 1989; Cabral and Riordan 1989; Averch and Johnson 1962). Regardless of the regulatory regime applied, the regulated TSO is given an allowed revenue cap determining how much the firm is entitled to earn.[7]

After it has been determined how much a TSO is entitled to earn, the second aspect of tariff regulation deals with how the TSO obtains the allowed revenues, i.e. how the allowed revenues are allocated over the various capacity products offered by the TSO. In this respect, the allowed revenue constraint in Eq. (1) is binding.[8]

$$\bar{R} \geq \sum_{i=1}^{n} capacity\, bookings_i^f \times tariff_i \tag{1}$$

According to the allowed revenue constraint, a TSO is granted a level of allowed revenues $\left(\bar{R}\right)$ for a specific period, which must not be exceeded by the aggregated expected revenues obtained at all network points ($i = 1, \ldots, n$) by forecasted (superscript *f*) capacity bookings and the tariffs.[9,10] Given an allowed revenue constraint, a TSO is supposed to prefer the set of tariffs, i.e. a tariff for all network points, which maximises the TSO's profits. As the regulatory authority regulates the total revenues, TSOs are assumed to be free to choose any set of tariffs provided that the allowed revenue constraint is met. This allows TSOs to shift forecasted revenues from one network point to another. To illustrate this, assume there are two network points with equal capacity bookings and tariffs. Total revenues do not change if one tariff is decreased while the other tariff is increased by the same amount. This implies that if one tariff increases, at least one other tariff must decrease to comply with the allowed revenue constraint. If one tariff decreases, this allows the TSO to raise another tariff without violating the constraint. This possibility of *revenue shifting* between network points allows for flexibility in setting tariffs. Since the capacity bookings and revenues in Eq. (1) include both capacities from IPs as well as capacities from domestic points, revenue shifting may take place not only inside a group of network points but also between them.

As the TSO's allowed revenues are set by a regulatory authority, they are exogenously given. Regarding the forecasted capacity bookings, which are used as an input to determine tariffs, two cases can be distinguished. Firstly, the regulatory

[7] Note that different terms may be used under different regulatory regimes, like allowed revenues, target revenues, total revenue cap. Although there may be differences in detail, all of them refer to the fact that regulation grants a certain level of revenues to be obtained by the TSO.

[8] Although tariffs are determined at a particular point in time for a particular period in the future, tariff calculation is static. To calculate the tariff at some point in time, also the allowed revenues and the capacity forecast valid for the same point in time are used. Hence, it is not necessary to consider a time dimension, which is therefore dropped for simplicity.

[9] Note that tariff calculation takes places prior to the tariff period, i.e. the period in which the tariffs are valid. Hence, the value for capacity bookings is always a forecasted one.

[10] In practice, TSOs offer different types of capacity products, particularly defined by runtimes. Considering this would result in another index of capacity bookings referring to the different capacity types, and the sum over the products would need to be considered. However, as this is not relevant here, we omit the distinction of different capacity products for simplicity, and only refer to capacity bookings.

authority, based on information provided by the TSO, makes a capacity forecast, or prescribes a methodology how the TSO must forecast capacity bookings. In this case, the TSO has the incentive to underestimate the capacity demand: if actual bookings exceed the forecasted ones; the TSO obtains extra revenues and profits. Therefore, the regulatory authority needs to control and/or set clear rules on how to forecast bookings. This points at the information asymmetries between the regulator and the regulated company; the TSO has a more detailed insight into market reactions than the regulatory authority. Such additional information may be an advantage in negotiating the forecasted capacity bookings to be used in determining tariffs. Such an approach related to forecast bookings is characteristic for a price-cap regime (Beesley and Littlechild 1989; Sibley 1989). Secondly, a regulatory authority may give freedom to the TSO forecasting capacity bookings. Since there is no interaction between the regulatory authority and the TSO required, it also overcomes the problem of information asymmetry. Such an approach is characteristic of a revenue-cap regime, which is the focus of this paper (Arcos-Vargas et al. 2017).[11]

Revenue-cap regulation has been applied in many US states to regulate electricity distribution companies with the aim of energy savings (Vogelsang and Cave 2019). Whereas a regulated firm under a price-cap regulation has the incentive to increase sales in order to minimise average costs, such an incentive does not exist under a revenue-cap regime, as it decouples the firm's revenues from its sales (Stoft 1995; Brennan 2010). In European energy markets, utilities are unbundled with energy networks being exposed to a regulation. Production, trading, and supply of energy are taken place in a competitive environment. Revenue-cap regulation, as applied in the European Union's gas markets, aims at shielding TSOs against volume related risks (CEER 2019; Economic Consulting Associates 2018). Gas consumption, for example, significantly depends on temperature. If the winter season is colder (warmer) than expected, the TSO will ceteris paribus end up with an over-recovery (under-recovery) due to a higher (lower) demand for transport capacity, derived from a higher (lower) demand for the commodity gas, Since demand is highly dependent on factors that cannot be influenced by the regulated TSOs, the regulatory authorities protect the regulated infrastructure operators from such a volume risk. This is discussed in more detail in the following Sect. 3.

3 Theoretical framework: tariff related incentives for TSOs under revenue-cap regulation

Assume a TSO operating under a revenue-cap regulation with a binding allowed revenue constraint as per Eq. (1). The revenue-cap gives the TSO the flexibility to choose amongst different combinations of tariffs and forecasted bookings, provided that the forecasted revenues to be obtained do not exceed the allowed revenues granted.

[11] We discuss revenue-caps in more detail in Sect. 3.

How would a TSO set its tariffs to maximise its profits? In general, revenue-cap regulation is associated with incentives to set prices. This has been criticised by Crew and Kleindorfer (1996) reflected in the so-called *Crew-Kleindorfer effect*: With revenues being capped, profit maximisation directly refers to cost minimisation. Since the firm's marginal costs increase in demanded quantities, the firm has the incentive to choose a higher price with a corresponding lower volume. This price may even exceed the monopoly price causing inefficiencies.

According to the Crew–Kleindorfer effect, a TSO could have the incentive to obtain its allowed revenues by setting high tariffs associated with low volumes to minimise costs. TSOs' costs are mainly related to pipelines investments, and hence are sunk. Nevertheless, a TSO may have limited marginal costs, for example for gas that is consumed by compressors, which are necessary to enable gas transports. In the regulatory practice in Europe, such costs are usually considered by the regulatory authority as so-called *pass-through costs* (Economic Consulting Associates 2018). Such costs are directly considered as an adjustment to the allowed revenues. Hence, even in case a TSO has non-negligible marginal costs, the Crew–Kleindorfer effect is not likely to apply.

Due to the allowed revenue constraint as per Eq. (1), a TSO under a revenue-cap generally faces a volume risk based on the difference between forecasted capacity bookings and actual bookings. If the actual bookings exceed (are less than) the forecasted ones, the TSO receives an over-recovery (under-recovery). As a measure to protect the regulated firm against volume risks on the demand side, regulatory authorities may introduce a so-called *regulatory account* (European Commission 2017b).

The regulatory account tracks over- and under-recoveries after each tariff period (t), to be reconciled in future periods.[12] The balance of the regulatory account (RA) at the end of tariff period t is given by Eq. (2), which shows that it is determined by two factors:

$$\begin{aligned} RA_t &= \Delta RA_{t-1,t} + \Delta R_t, \quad \text{with} \\ \Delta RA_{t-1,t} &= (1+i)\left[(1-a)RA_{t-1}\right], \quad \text{and} \\ \Delta R_t &= \bar{R}_t - Tar_t \times CB_t \end{aligned} \tag{2}$$

Firstly, ΔR_t refers to the difference in period t between the allowed revenues ($\bar{R}_t$), and the revenues actually obtained, i.e. the tariff (Tar_t) multiplied by the actually demanded capacity bookings (CB_t). Therefore, this represents the over- or under-recovery due to the difference of expected and actual quantities. Secondly, $\Delta RA_{t-1,t}$ refers to the regulatory account's balance at the end of the previous tariff period (RA_{t-1}), taking into account the reconciliation during this period (a) and interests $(1+i)$. The parameter a defines how much of an over- or under-recovery is reconciled each tariff period. Hence, $a = 1/n$, with n standing for the number of tariff

[12] For clarity, tariff period refers to the period during which a tariff is valid, for example, a calendar year. This needs to be distinguished from the regulatory period, which is usually longer, and refers to the period during which the general rules for the allowed revenues are set (European Commission 2017b).

periods it takes to fully reconcile an over- or under-recovery. In general, the longer it takes to fully reconcile an over- or under-recovery, ceteris paribus, the lower the volatility of tariffs. Thus, the parameter a only affects liquidity. Following this, $(1-a)RA_{t-1}$ denotes the remaining balance of the regulatory account, which has not been reconciled yet. $(1+i)$ ensures the regulatory account bears interests.

To effectively shield the TSO from volume risk, as intended by the regulation, the revenue cap is adjusted each tariff period by a fraction of the regulatory account, shown by Eq. (3).[13]

$$R_t = R_{t-1} + aRA_{t-1}. \tag{3}$$

As it is the intention of the regulatory account to protect the regulated TSO against volume risk, its inclusion in determining the allowed revenues makes the firm indifferent to the demanded volumes. Ultimately, the TSO will at no risk obtain the allowed revenues granted, not more and not less. As the TSO does not bear the volume risk, the volume risk is borne by the network users. Only looking at this aspect, TSOs have no incentive to set tariffs such that they are cost-reflective or aim at allocative efficiency.

However, there is another mechanism by which network utilisation affects incentives to set the tariffs. This mechanism is related to how the level of allowed revenues are determined. In general, the allowed revenues are based on the regulated firm's costs, insofar as they are viewed to be efficient. Movements in efficiency are divided into *frontier shift* and *catch-up* (Giannakis et al. 2005). Frontier shift describes technological progress and innovation allowing for an increase of productivity. The frontier represents the maximum productivity feasible by objective standards. Catch-up measures the firm's movement towards the frontier. It measures the productive efficiency between several firms, also referred to as benchmarking.

In regulating TSOs in Europe, the firm's efficient costs are determined through benchmarking. Benchmarking, in simplified terms, describes a measure of comparing a firm's output-input ratio (i.e. the productivity), within a peer group (Jamasb and Pollitt 2003). Such benchmarking is performed periodically and leads to an individual efficiency score for each TSO. Equation (4) highlights that the efficiency score (ES) of firm i depends on the firm's output-input-ratio compared to the same ratio calculated for a benchmark j, which may be a single (best practice) firm, or an average of the peer group. As for TSOs, the input refers to the firms' costs. Output refers to the networks' capacity as well as the utilisation, i.e. capacity bookings (Mulder 2012).[14]

[13] This is a simplified representation to show the impact of the regulatory account on the allowed revenues. Therefore, other elements, for example adjustments according to inflation or efficiency targets are not considered.

[14] It may be argued the output is not capacity bookings but the actual utilisation. However, in order to utilise the network, capacity bookings are necessary which is why these are directly related.

$$ES_i = \frac{(output/input)_i}{(output/input)_j} \tag{4}$$

The efficiency score directly impacts the TSO's allowed revenues. To illustrate this, we for simplicity assume the allowed revenues ($\bar{R}$) of a regulatory period (*rp)* depend only on the firm's total expenditures (*TOTEX*), and on its efficiency score (*ES*). Then, $\bar{R}_{rp} = TOTEX_{rp-1} \times ES_{rp-1}$. Taking account of this relationship the TSO has an incentive to increase its efficiency. Noting that marginal costs are negligible, this implies that the regulated firm may want to set the tariffs such that it increases the utilisation of the network, and hence the firms efficiency score, to obtain higher revenues and profits in the next regulatory period.

A regulatory account shields a TSO operating under a revenue-cap regime from volume risk within a regulatory period. However, it does not shield the TSO from volume related changes to its efficiency score, which affects the revenues in the next regulatory period. For example, assume a TSO is faced with a continuous decline in demand for its gas transport capacities. If the TSO anticipates this decline perfectly by adapting its tariffs, there are no over- or under-recoveries tracked on the regulatory account. However, the firm's efficiency ceteris paribus is supposed to decrease if cost, being inputs to the benchmarking, are constant while the outputs continuously decline. By objective standards, the TSO ceteris paribus becomes less efficient as it diverges from the efficiency frontier.

By way of illustration, assume a peer group of two TSOs. Furthermore, assume TSO 1 ceteris paribus faces lower capacity bookings while these are constant for TSO 2. If the benchmark is based on the average of both TSOs, or is determined as best practice, TSO 1 becomes less productive efficient whereas TSO 2 increases its relative efficiency; the efficiency scores change likewise. Since the efficiency score affects the allowed revenues ceteris paribus TSO 1 will be granted lower allowed revenues, whereas TSO 2 will be granted higher allowed revenues. This example highlights that TSOs have an incentive to increase capacity bookings to obtain a higher network utilisation. This should be considered in setting tariffs.

Until now, we have elaborated on tariff related incentives for TSOs under revenue-cap regulation without considering market mergers. As highlighted in Sect. 2.1, a result of gas market mergers is that different TSOs may offer transport capacity between the same gas market areas. This implies that network users requesting transport capacity have a choice between different TSOs offering transport capacity at a particular border. Take again the example assuming a market merger has taken place. Furthermore, assume both TSO 1 and TSO 2 offer capacity at the same border. While before the merger, TSO 1 and TSO 2 competed only in the sense that both belong to the same peer group, after the merger they directly compete for the same demand. Assuming total demand is constant, each TSO has the incentive to charge lower tariffs such that it can attract demand served by the other TSO. Hence, the two TSOs directly compete for the same demand which gives an additional incentive to set lower tariffs to obtain higher capacity bookings, and a higher network utilisation.

We conclude that TSOs operating under a revenue-cap regime have tariff related incentives. However, this incentive is not based on capping the maximum revenues but results from an efficiency benchmarking. Thus, TSOs have incentives to reduce their costs per unit of output as well as to set tariffs such that the firm obtains higher capacity bookings; both increase efficiency which increases allowed revenues and profits. This holds regardless of whether a market merger has taken place. However, in a merged market where TSOs now directly compete for the same demand at the borders, competition is supposed to be even stronger. Therefore, ceteris paribus we expect lower tariffs at borders at which different TSOs offer transport capacity compared to those borders at which only one TSO offers transport capacity.

4 Empirical analysis

4.1 Empirical model

Our hypothesis about the impact of market mergers, resulting in choices for network users, on TSOs' tariffs is tested by a panel data analysis. Tariffs are set periodically by TSOs. Therefore, panels may be created using TSOs represented by $k = 1, \dots, m$ that set tariffs for a tariff period t for an IP located at a border $i = 1, \dots, n$. For each t, this results in a $m \times n$ matrix. As Fig. 1 highlights, not every TSO has an IP at every border. Therefore, data are not available for every TSO at every border, which is why such a panel is highly unbalanced. To overcome this in our model the cross-section dimension is the border i of gas market areas and not individual TSOs. In constructing our panels, we consider the flow directions and differences in gas qualities.[15] This is supposed to make the panels more balanced as there are tariffs available at every border. More information about the actual panel is presented in Sect. 4.2

If more than one TSO is offering capacity at a border there are different tariffs applicable at that border at the same time. Therefore, tariffs observed cannot be used as the independent variable if the cross-section refers to borders. To be able to analyse whether certain explanatory variables lead to higher or lower tariffs we estimate the same empirical model choosing both the minimum tariff and the maximum tariff as the dependent variable. To control for outliers, we also estimate the model using the median tariff of a border as a dependent variable.

Our null hypothesis is that tariff levels are affected by the network users' possibility to choose amongst alternative TSOs. Therefore, we include a dummy variable dS denoting whether substitutes, i.e. capacity is offered by different TSOs, are available to networks users, with $dS_{i,t} = 1$ if the number of TSOs offering capacity at a border i in t exceeds 1, and 0 otherwise.

Complying with the allowed revenue constraint TSOs may shift revenues to be obtained between IPs and points with captive demand. Hence, it allows for avoiding competition. This is taken account of by the dummy variable $dCD_{i,t} = 1$ if the

[15] Depending on the source, the calorific value of gas varies. In general, a high calorific gas (H-gas) and a low calorific gas (L-gas) are distinguished (Ströbele et al. 2012). This distinction may also be made in transmission capacities. This is distinction is made, for example, in Germany.

number of TSOs offering capacity at a border i in t and having captive demand exceeds 0, and 0 otherwise.

To control for congestions, i.e. a scarcity of capacity, a dummy variable $dCo_{i,t}$ is included in the model. It is defined as $dCo = 1$ if the number of congested IPs at border i in t exceeds 0, and 0 otherwise.

As the tariffs are set by regulated firms, the allowed revenue constraint is binding in setting tariffs. Thus, the model needs to consider capacity bookings and allowed revenues. This constraint is binding to every TSO individually. However, the dependent variable is a specific tariff observed at a border. To reflect this, the model takes into account the average of allowed revenues of all TSOs $k = 1, \dots, m$ at border i in t, i.e. $\frac{\sum_{k=1}^{m} AR_{k,i,t}}{m_{i,t}}$. For the same reason we include the average of capacity bookings of all TSOs $k = 1, \dots, m$ at border i in t, i.e. $\frac{\sum_{k=1}^{m} CB_{k,i,t}}{m_{i,t}}$.

As tariff setting takes place prior to the tariff period for which tariffs are set, and tariffs may not be changed during a tariff period, some of the variables used in the model are forecasts made by the TSOs. Changes in the market structure and to the networks do not happen on short notice. Therefore, TSOs are supposed to know how many TSOs operate how many IPs in the upcoming tariff period and whether network users have a possibility of substitution. The same holds irrespective whether TSOs have captive demand or not, which is publicly available information. Hence, no forecasts are necessary concerning these two variables. In terms of congestion, this is different. A TSO cannot know with certainty prior to the tariff period whether an IP will be congested. Therefore, the TSO must predict this. The same holds for the capacity bookings. A TSO may already have contracts concluded before the tariff period. However, additional capacity bookings may be obtained during the tariff period. Forecasted capacity bookings at other TSOs are also unknown and must be predicted. Thus, the average capacity booking level per TSO is also a forecasted value. In contrast, a TSO knows the own allowed revenues applicable for the upcoming tariff period at the point in time the tariffs are set. On the other hand, a TSO is not aware of the allowed revenues of the other TSOs at the point in time the tariffs are set. Therefore, the average allowed revenues per TSO is also a forecasted value.

As the aim is to assess elasticities measuring relative changes, we use log–log models. In case a variable is a forecasted one, this is highlighted by a superscript f. As the models are estimated by fixed effects, a variable covering period fixed effects (β_t), such as general changes in costs of capital or in inflation, and one variable covering cross-section fixed effects (β_i) representing unobserved heterogeneity are included. The model is given by Eq. (5).

$$\begin{aligned} ln(Tar^{s}_{i,t}) = \beta^{s}_{i} + \beta^{s}_{t} + \beta^{s}_{1} dS_{i,t} + \beta^{s}_{2} dCD_{i,t} + \beta^{s}_{3} dCo^{f}_{i,t} \\ + \beta^{s}_{4} \ln\left(\frac{\sum_{k=1}^{m} AR^{f}_{k,i,t}}{m_{i,t}}\right) + \beta^{s}_{5} \ln\left(\frac{\sum_{k=1}^{m} CB^{f}_{k,i,t}}{m_{i,t}}\right) + u^{s}_{i,t} \end{aligned} \tag{5}$$

whereby the selected sample s = minimum, maximum, and median tariffs.

The expectations for the coefficients estimated are determined by the regulatory regime of the data, to which the model is applied. As we apply the model to a revenue-cap regime with benchmarking we expect for each sample s, in line with our theoretical analysis, $\beta_1 < 0$ and $\beta_2 < 0$. In case one TSO faces other TSOs offering capacity at the same border ($dS_{i,t} = 1$) we ceteris paribus expect tariffs at this border to be lower as compared to borders where a single TSO offers capacity. In case the TSOs have captive demand, the firms can more effectively shift revenues to be obtained to points with rather inelastic demand for capacity.

TSOs aim at higher capacity bookings. However, in case of scarcity capacity bookings cannot be increased in the short run. Therefore, there is no incentive to ceteris paribus apply lower tariffs at congested borders. On the contrary, with a binding allowed revenue constraint higher tariffs at congested borders even allow for lower tariffs at other borders showing a higher elasticity. Therefore, we expect $\beta_3 > 0$ for each sample s.

According to the allowed revenue constraint tariffs are ceteris paribus supposed to be higher if the allowed revenues increase. If capacity bookings increase tariff should decrease. Therefore, we expect $\beta_4 > 0$ and $\beta_5 < 0$ for each sample s. However, if we would obtain estimates for β_4 and β_5 that are not significantly different from zero, this may point at TSOs shifting revenues towards domestic points.

4.2 Data

After several market mergers in the past, today, Germany has 16 TSOs offering transport capacity in two market areas, namely GASPOOL and NetConnect Germany (hereafter: NCG). These TSOs are regulated by revenue-cap regime and exposed to an efficiency benchmarking (Economic Consulting Associates 2018). Therefore, we test our hypothesis using data for Germany.

Data for IP tariffs are provided by ACER (2019a). This data set contains the cost of flowing 1 MWh through an IP on a firm basis in EUR/MWh for all IPs across Europe.[16] In case different types of firm capacity are offered the tariff refers to the best available capacity type. The data set covers the period from 2014 to 2018. Besides that, data of the IP's TSO, the border of connected market areas, and the flow direction are available. In line with the empirical model the tariff data are grouped by borders distinguishing flow directions and gas qualities. Hence every group of data has either entry or exit flow direction and is either H-gas or L-gas. After having grouped the data per border the number of active TSOs at a border is determined. To estimate the model not only the total number of TSOs operating at a border is necessary but also how many of these TSOs have captive demand. This information can be obtained directly from the TSOs' websites.

ACER publishes an annual report on contractual congestion at interconnection points (ACER 2019b). The findings of the reports covering the years 2014–2018 are

[16] In general, there are two categories of transmission capacities: Firm capacity grants the right to network users to transport gas without any risk of being interrupted. Interruptible capacity may be interrupted by the TSO, for example, to ensure security of supply (European Parliament and Council of the European Union 2009a). In some countries, for example Germany, different types of firm capacity may be offered. Their difference refers to potential conditions of firmness or gas routes. For additional information see BDEW (2019).

linked to the IPs of the tariff data set. An IP may either be congested if the IP itself is congested, or if the adjacent IP is congested. In the latter case, an IP on the German side may have free capacity to offer, however, there is no corresponding capacity available on the other side of the border.

To control for changes in tariffs based on changes in allowed revenues data on allowed revenues for 2014–2018 are necessary. Although TSOs operate under wide-ranging transparency obligations, allowed revenues are not published for the period that we analyse. The main driver of the allowed revenues is the so-called *regulated asset base* (hereafter: RAB). Therefore, the RAB may be used as a proxy for the allowed revenues. However, also data on RAB are not available. However, TSOs' annual reports show the value of fixed assets. Fixed assets and RAB are based on the same items and are supposed to be strongly correlated. The difference solely refers to differences in depreciation periods. Therefore, we use the book value of fixed assets as a proxy for the RAB to determine the forecasted allowed revenues. There are also joint venture pipelines, whose capacity is offered by the shareholder TSOs. In such a case, we allocate the value of fixed assets directly to the shareholders based on the ownership structure.

Data on capacity bookings are collected from the transparency platform operated by ENTSOG (2019). This transparency platform publishes, among others, data on capacity bookings at IPs. Capacity bookings are distinguished between firm and interruptible capacity. In determining tariffs interruptible capacity is usually given a discount to compensate for the risk of being interrupted. In return this means that booking one unit of firm capacity contributes more to revenues than booking one unit of interruptible capacity because of the discount. Also, within the group of firm capacity bookings there are differences. There are different types of firm capacities that may be offered at an IP. These different types may receive a discount due to quality differences. Furthermore, a so-called *multiplier* may be added to capacity booking of firm as well as of interruptible capacity with the intention to stimulate long-term bookings by making them relatively cheaper compared to short-term bookings. Also, seasonal factors may be applied. All these may cause an inaccuracy of data. The capacity bookings reported by the transparency platform are aggregated bookings of network users. However, the value of one unit of capacity booked may be higher or lower, depending on discounts granted and multipliers applied. Such information is not available, which needs to be considered analysing the estimates of the empirical model.

As tariffs of a TSO are based on the sum of all forecasted capacity bookings, it is not sufficient to consider IP bookings only. The ENTSOG transparency platform also shows capacity at domestic points. The platform contains all capacity bookings levels for each TSO except exit capacity bookings to downstream distribution system operators, necessary to supply households. However, we may assume this capacity to be relatively constant over time, hence it is captured by the period fixed effect. Therefore, there is no need to consider these data, which are not available for all TSOs for the respective period.

The model in Sect. 4.1 uses forecasted values for the dummy indicating congestion, the average RAB, used as a proxy for the average allowed revenues, and the average capacity bookings. Therefore, a decision must be made on how to forecast

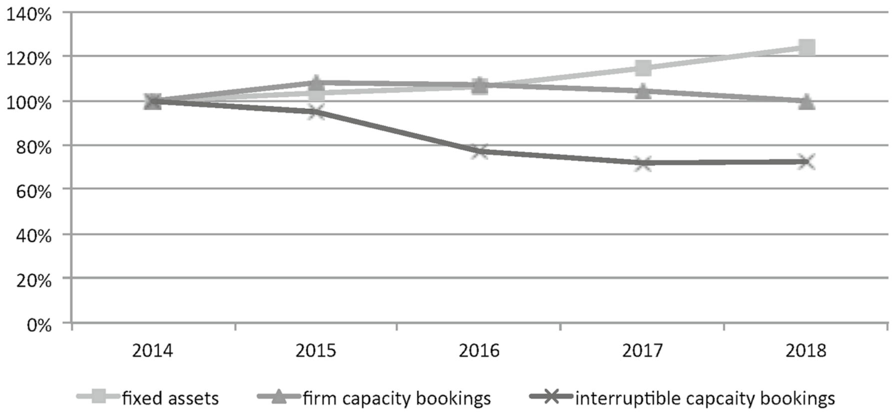

Fig. 2 Index representation of the sum of fixed assets, firm capacity bookings and interruptible capacity bookings for all German TSOs in 2014 (=100%) to 2018, source: Bundesanzeiger (2019) and ENTSOG (2019); own calculations

Table 1 Distribution of TSOs and congested IPs in the sample in 2014–2018 offering capacity at a border

Number of TSOs active at a border	All TSOs		TSOs with captive demand		Congested IPs	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
0	0	0	2	1.21	134	81.21
1	72	43.64	79	47.88	18	10.91
2	52	31.52	65	39.39	10	6.06
3	35	21.21	16	9.70	3	2.82
4	6	3.64	3	1.82	0	0
Total	165	100	165	100	165	100

these. We assume the best forecasted values are given by the latest actual values. This means that $dCo^f_{i,t} = dCo_{i,t-1}$, $CB^f_{k,i,t} = CB_{k,i,t-1}$, and $RAB^f_{k,i,t} = RAB_{k,i,t-1}$. For consistency reasons, averages are calculated for the number of TSOs in $t-1$ as well. In the remainder we drop time indices and indicate lags by the supplement (-1). Because of using lagged variables, the period of the analysis covers 2015 to 2018. Introducing lagged dependent variables avoids the endogeneity bias due to reverse causation.

During the period of observation, a market merger between Belgium and Luxembourg took place. As for the data set, we ignore this merger by integrating the gas market area of Luxembourg in the Belgian one. After this adjustment, the data set is strongly balanced with borders $i = 1, \ldots, 35$ and $t = 2015, \ldots, 2018$, i.e. four observations for 35 cross-sections.

Figure 2 plots the sum of the book value of the fixed assets, and capacity bookings for firm and interruptible capacities for all German TSOs in 2014 to

Table 2 Joint distribution of TSOs with captive demand, and all TSOs in the sample in 2014–2018

Total number of TSOs	Number of TSOs with captive demand					
	0	1	2	3	4	Total
1	2	70	0	0	0	72
2	0	6	46	0	0	52
3	0	0	19	16	0	35
4	0	3	0	0	3	6
Total	2	79	65	16	3	165

2018 using an indexed representation with 2014 = 100%. The figure shows a positive trend for the sum of fixed assets during the period with a compound annual growth rate (hereafter: CAGR) of 5.45%. Firm capacity is constant over the period (CAGR: − 0.02%). In contrast, interruptible capacity bookings show a negative trend (CAGR: − 7.66%).

Table 1 shows the distributions of the total number of TSOs, the number of TSOs with captive demand, and the number of congested IPs. The first column shows the number of TSOs offering capacity at the same border. This table shows that most observations have only one TSO offering capacity at border (43.64%). However, also two TSOs (31.52%) and three TSOs (21.21%) appear relatively often. For the number of TSO with captive demand, the distribution is slightly different. 87.27% of the observations show either one TSO with captive demand (47.88%) or two (39.39%). Three TSOs with captive demand are observed in 9.70% of all cases. In a very few cases (1.21%), a border does not have any TSO with captive demand. In terms of congestions, 81.21% of all IPs are not congested.

A joint distribution of the total number of TSO and the number of TSOs having captive demand (Table 2) shows that in case only one TSO offers capacity at a border, there are only two observations with a TSO having no captive demand. Additionally, there are no observations with more than one TSO, whereby at least one TSO has captive demand. For the empirical model, this implies that $dCD = 1$ if $dS = 1$. However, if $dS = 0$, $dCD = 0$ only in two cases. Based on only two observations, no reliable estimates for dCD can be expected. Therefore, we drop the variable from the model, and assume $dCD = 1$. In terms of dS, the dummy is 0 in approximately 44% of all observations, and 1 in about 56%. Hence, the data set is balanced in this respect.

To check the data set for stationarity, unit root tests may be applied. However, the power of these tests is low due to the sample size. Results of testing for cointegration are also not reliable given the length of the time series. Nonetheless, there is a logical relationship between tariffs, allowed revenues and capacity bookings, which is the allowed revenue constraint as pointed out in Sect. 2.2. Therefore, we expect the variables to be cointegrated. Hence, the regressions are not spurious, and the fixed effects estimators are consistent.

Table 3 Estimates for the period 2015–2018: Dependent variables $ln\left(Tar^{min}\right)$, $ln(Tar^{max})$, and $ln\left(Tar^{median}\right)$ (robust standard errors in parentheses, cross-section fixed effects are not reported)

	$ln\left(Tar^{min}\right)$	$ln(Tar^{max})$	$ln\left(Tar^{median}\right)$
dS	−0.5161***	−0.0783***	−0.2854***
	(0.0605)	(0.0196)	(0.0199)
$dCo(-1)$	−0.0887	0.0028	0.0030
	(0.0767)	(0.0398)	(0.0440)
$\ln\left(\frac{\sum_{k=1}^{m} RAB_k(-1)}{m(-1)}\right)$	−0.0176 (0.3250)	0.2319** (0.0883)	0.3753*** (0.0844)
$\ln\left(\frac{\sum_{k=1}^{m} CB_k(-1)}{m(-1)}\right)$	−0.1702 (0.1742)	−0.1523*** (0.0465)	−0.2298*** (0.0484)
Constant	4.0201	−1.5079	−2.3320
	(3.5598)	(1.7745)	(1.5744)
Period fixed effects			
2016	−0.0866	−0.0373*	−0.0412*
	(0.0624)	(0.0196)	(0.0217)
2017	−0.0791	−0.0179	−0.0328
	(0.0772)	(0.0241)	(0.0251)
2018	−0.0164	0.0464	0.0143
	(0.0592)	(0.0352)	(0.0322)
observations =	131	131	131

Two-tailed p values: *$p<0.10$; **$p<0.05$; ***$p<0.01$

dS is the dummy variable denoting the difference between borders, where more than on TSO offers capacity ($dS = 1$), and those where capacity is offered only by one TSO ($dS = 0$)

$dCo(-1)$ is the difference between congested and non-congested borders, with a one-period lag

$ln\left(\frac{\sum_{k=1}^{m} RAB_k(-1)}{m(-1)}\right)$ is the average RAB per TSO active at a border, one-period lagged

$ln\left(\frac{\sum_{k=1}^{m} CB_k(-1)}{m(-1)}\right)$ is the average capacity bookings per TSO active at a border, one-period lagged

One observation is dropped from the regressions due to the condition $dCD = 1$, see Sect. 4.2. Considering this observation, mainly impacts the estimates concerning the minimum tariff

4.3 Results

Table 3 shows the estimated results of the model for minimum, maximum, and median tariffs at borders as developed in Sect. 4.1 with the adjustments to the data as explained in Sect. 4.2 including cross-section fixed effects and period fixed effects. Tests reveal that the fixed-effects estimators are consistent.

Dummy variable dS denotes the difference between borders where more than on TSO offers capacity ($dS = 1$), and those, where capacity is offered only by one TSO ($dS = 0$). Variable $dCo(-1)$ is a one-period lagged dummy variable that points out the difference between congested and non-congested borders. The variable $\ln\left(\frac{\sum_{k=1}^{m} RAB_k(-1)}{m(-1)}\right)$ is the average RAB per TSO active at a border, and

$\ln\left(\frac{\sum_{k=1}^{m} CB_k(-1)}{m(-1)}\right)$ stands for the average total capacity bookings per TSO active at a border; both use one period lagged data as a forecast as set out in Sect. 4.2.

The variable dS indicates whether a network user has a choice between different TSOs' IPs at a particular border. For a revenue-cap regime with efficiency benchmarking our theoretical assessment expects (in the short term) lower tariffs in case not only one but more than one TSO offers capacity at a border, i.e. $dS = 1$. The results show that for all dependent variables, the minimum (−51.61%), maximum (−7.83%) and median tariff (−28.54%), are significantly lower in case more than one TSO offers capacity at a border. Such results point at tariff adjustments made by TSOs as a response to the existence of substitutes to network users. This is in line with our hypothesis.

Forecasted congestions do not show a significant effect on tariffs in two-tail tests at usual levels of significance. This is not in line with our expectation.

The estimated marginal effect of the forecasted average allowed revenues is −0.02% in case of the minimum tariffs, 0.23% in case of the maximum tariffs, and 0.38% in case of the median tariffs. Whereas the estimates for the median ($p<0.01$) and the maximum tariffs ($p<0.05$) are significant, the estimates for the minimum tariffs are insignificant ($p>0.10$).

The estimated marginal effects of the forecasted average capacity bookings are −0.17%, −0.15%, and −0.23% (for minimum, maximum, and median tariffs, respectively). These estimates are significant with $p<0.01$ for both maximum and median tariffs, and insignificant at usual levels of significance in case of minimum tariffs.

Comparing the results obtained with our expectations stated in Sect. 4.1, there is a positive coefficient related to the forecasted average allowed revenues, as expected. Furthermore, estimates for the forecasted average capacity bookings are negative, as expected. This confirms the allowed revenue constraint, except for the estimates for the minimum tariffs, which are not significant. Insignificant marginal effects indicate that TSOs do not increase or decrease tariffs at IPs in relation to changes in allowed revenues or capacity bookings. This is an indication that TSOs may set the tariffs in response to each other.

4.4 Sensitivity analysis: test for structural differences

The main results presented in the previous section are in line with our expectations, which are based on the incentives for TSOs under revenue-cap regulation with an applied efficiency benchmarking, as explained in Sect. 3. The results point out that tariff adjustments are made by TSOs as a response to inter-TSO competition for volumes. However, TSOs differ in their nature. TSOs may be distinguished into two groups. On the one hand, there are wide-ranging meshed networks to transport gas to industrial customers and to distribution systems to supply end customers. On the other hand, there are transit TSOs that operates as a kind of interconnector between two markets. As a sensitivity analysis, we apply the same method as in the previous section to two subsets. Subset 1 includes all panels with transit TSOs only, subset 2 includes all panels with meshed TSOs only. However, subset 1 is an empty set since there are no observations. For the subset of meshed TSOs we expect no differences with the results presented in Sect. 4.3 for the full sample, which is confirmed by our estimations.[17] Regarding the set of meshed TSOs, minimum tariffs also appear to be more than 50% lower in case more than one TSO offers capacity at a border. Based on this, we conclude that the results presented in Sect. 4.3 are robust to structural differences between TSOs.

5 Conclusions

To reduce barriers to trade, and to increase wholesale market liquidity and competition, market mergers are observed in European gas markets. Such market mergers have taken place, for example within France and Germany, and even between countries, for example between Belgium and Luxembourg. Future mergers are expected not at least because regulatory authorities aim at further improving the functioning of wholesale markets (ACER and CEER 2015). Market mergers do not only impact commodity wholesale markets, but also provide network users with the choice to book transport capacity at different gas transmission system operators. As network users make efficient choices, they are sensitive to tariff differences, which implies that inter-TSO competition may be possible at certain borders of merged gas markets (Keller et al. 2019).

Our paper extends the literature on (de-)regulation of natural monopolies. However, compared to other work, like for example Cave (2004, 2014) our perspective is different, since potential competition arises from merging markets with regulated monopolies, and does not arise from unregulated new entrants in the market. Also in contributing to the future of tariff regulation in European gas markets our focus differs from other studies that do not take account of market mergers and their impact on the potential for inter-TSO competition (for example, see Cervigni et al. 2019; EY and REKK 2018; Hecking 2015).

We investigate tariff related incentives for TSOs that are regulated by a revenue-cap regime which is the most common regulatory regime applied in European gas markets (Economic Consulting Associates 2018). The theoretical analysis of this paper shows that TSOs operating under a revenue-cap regime have an incentive to reduce tariffs to increase allowed revenues and profits. This incentive is not based on capping maximum revenues but results from efficiency benchmarking. As a TSO's efficiency, i.e. its productivity compared to a benchmark, impacts its allowed revenues and profits, the regulated firm has the incentive to increase efficiency. As higher capacity bookings, ceteris paribus, increase the firm's efficiency, the TSO has the incentive to charge lower tariffs to obtain higher capacity bookings.

In an unmerged market, TSOs compete by reducing their costs per unit of output compared to the peer group used for efficiency benchmarking. In a merged market, TSOs have an additional incentive as they also compete directly for the

[17] The comparison of the estimates is provided in "Appendix".

same demand at borders where more than one TSO offers capacity. Thus, this tariff related incentive is supposed to be even stronger in this situation, created by a market merger. Therefore, lower tariffs are expected at borders, at which more than one TSO offers capacity, compared to those borders, at which only one TSO offers capacity.

This hypothesis is tested with a panel data set of tariffs charged by German TSOs covering the period 2015–2018. We find that tariffs are up to 52% lower in situations, where capacity at border is offered by more than one TSO. This is in line with our hypothesis. A sensitivity analysis shows that this result is robust to structural differences between transit and meshed networks. For Germany, where TSOs operate in merged markets and under a revenue-cap regime with efficiency benchmarking, we conclude that TSOs have an incentive to reduce tariffs at network points, where they compete for demand. Our empirical analysis confirms our expectations.

Our results show that inter-TSO competition under revenue-cap regulation is possible if an efficiency benchmarking is applied. A merger of gas markets does not impact the physical structure of networks and even gas flows may remain unaffected. Nevertheless, a market merger has an impact on inter-TSO competition since it enhances the tariff related incentives that result from applying an efficiency benchmarking. As regulation is deemed necessary in case of lacking competition, future research should investigate the consequences of such inter-TSO competition for the regulatory framework and assess the possibility for changes to the regulation including potential deregulation.

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Availability of data and material Not applicable.

Compliance with ethical standards

Conflicts of interest The corresponding author is employed by Gastransport Nord GmbH, Germany.

Code availability Not applicable.

Appendix: Sensitivity analysis: testing for structural differences

To verify structural differences between transit and meshed TSOs, the empirical model is estimated using the full sample and the two subsets as defined in Table 4. The results are shown in Table 5. As there are no observations for subset 1, the table allows only for a comparison of the full sample and subset 2.

Table 4 Definitions and number of observations of data sets used for a subset analysis, covered period 2015–2018

Data set	Definition	Observations
Full sample	All borders as used in Sect. 4.3 of this paper	131
Subset 1	All borders, at which only transit TSOs offer capacity	0
Subset 2	All borders, at which only meshed TSOs offer capacity	88

Table 5 Estimates for different data sets for the period 2015–2018: Dependent variables $ln\left(Tar^{min}\right)$, $ln(Tar^{max})$, and $ln\left(Tar^{median}\right)$ (robust standard errors in parentheses, cross-section fixed effects are not reported)

	$ln\left(Tar^{min}\right)$		$ln(Tar^{max})$		$ln\left(Tar^{median}\right)$	
	Full sample	Subset 2	Full sample	Subset 2	Full sample	Subset 2
dS	−0.5161***	−0.5425***	−0.0783***	−0.0793**	−0.2854***	−0.2725***
	(0.0605)	(0.0218)	(0.0196)	(0.0315)	(0.0199)	(0.0263)
$dCo(-1)$	−0.0887	−0.1223**	0.0028	−0.0903***	0.0030	−0.1264***
	(0.0767)	(0.0503)	(0.0398)	(0.0243)	(0.0440)	(0.0281)
$\ln\left(\frac{\sum_{k=1}^{m} RAB_k(-1)}{m(-1)}\right)$	−0.0176	0.4282***	0.2319**	0.2780***	0.3753***	0.3648***
	(0.3250)	(0.1030)	(0.0883)	(0.0786)	(0.0844)	(0.0803)
$\ln\left(\frac{\sum_{k=1}^{m} CB_k(-1)}{m(-1)}\right)$	−0.1702	−0.2510***	−0.1523***	−0.1774***	−0.2298***	−0.2249***
	(0.1742)	(0.0567)	(0.0465)	(0.0397)	(0.0484)	(0.0388)
constant	4.0201	−2.8622	−1.5079	−1.7757*	−2.3320	−2.2735
	(3.5598)	(2.4393)	(1.7745)	(0.9597)	(1.5744)	(1.3952)
Period fixed effects						
2016	−0.0866	−0.0747**	−0.0373*	−0.0753***	−0.0412*	−0.0676**
	(0.0624)	(0.0343)	(0.0196)	(0.0228)	(0.0217)	(0.0239)
2017	−0.0791	−0.0777**	−0.0179	−0.0582**	−0.0328	−0.0729***
	(0.0772)	(0.0285)	(0.0241)	(0.0267)	(0.0251)	(0.0245)
2018	−0.0164	−0.0365	0.0464	0.0153	0.0143	−0.0173
	(0.0592)	(0.0377)	(0.0352)	(0.0357)	(0.0322)	(0.0315)
Observations	131	88	131	88	131	88

Two-tailed p values: $^{*}p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$

dS is the dummy variable denoting the difference between borders, where more than on TSO offers capacity ($dS = 1$), and those where capacity is offered only by one TSO ($dS = 0$)

$dCo(-1)$ is the difference between congested and non-congested borders, with a one-period lag

$ln\left(\frac{\sum_{k=1}^{m} RAB_k(-1)}{m(-1)}\right)$ is the average RAB per TSO active at a border, one-period lagged

$ln\left(\frac{\sum_{k=1}^{m} CB_k(-1)}{m(-1)}\right)$ is the average total capacity bookings per TSO active at a border, one-period lagged

References

ACER. (2019a). Evolution of EU IP Tariffs 2013-2018 euros/MWh. https://aegis.acer.europa.eu.
ACER. (2019b). ACER annual report on contractual congestion at interconnection points: covered period 2013–2018. https://www.acer.europa.eu.
ACER & CEER. (2015). European gas target model review and update. https://www.acer.europa.eu.
Arcos-Vargas, A., Núñez, F., & Ballesteros, J. A. (2017). Quality, remuneration and regulatory framework: Some evidence on the European electricity distribution. *Journal of Regulatory Economics, 51*(1), 98–118.
Armstrong, M., & Sappington, D. E. M. (2006). Regulation, competition, and liberalization. *Journal of Economic Literature, 44*(2), 325–366.
Averch, H., & Johnson, L. L. (1962). Behavior of the firm under regulatory constraint. *American Economic Review, 52*(5), 1052–1069.
Baumol, W. J. (1982). Contestable markets: An uprising in the theory of industry structure. *American Economic Review, 72*(1), 1–15.
BDEW. (2019). Kooperationsvereinbarung zwischen den Betreibern von in Deutschland gelegenen Gasversorgungsnetzen. https://www.bdew.de/.
Beesley, M. E., & Littlechild, S. C. (1989). The regulation of privatized monopolies in the United Kingdom. *RAND Journal of Economics, 20*(3), 454–472.
Braeutigam, R. R., & Panzar, J. C. (1989). Diversification incentives under "Price-Based" and "Cost-Based" regulation. *RAND Journal of Economics, 20*(3), 373–391.
Brennan, T. J. (2010). Decoupling in electric utilities. *Journal of Regulatory Economics, 38*(1), 49–69.
Bundesanzeiger. (2019). Rechnungslegung/Finanzberichte. https://www.bundesanzeiger.de.
Cabral, L. M. B., & Riordan, M. H. (1989). Incentives for cost reduction under price cap regulation. *Journal of Regulatory Economics, 1*(2), 93–102.
Cave, M. (2004). Remedies for broadband services. *Journal of Network Industries, 5*(1), 23–49.
Cave, M. (2014). The ladder of investment in Europe, in retrospect and prospect. *Telecommunications Policy, 38,* 674–683.
CEER. (2019). Report on regulatory frameworks for European energy networks. https://www.ceer.eu/.
Cervigni, G., Conti, I., Glachant, J. M., Tesio, E., & Volpato, F. (2019). Towards an efficient and sustainable tariff methodology for the European Gas transmission network. Florence School of Regulation. Research Report. https://fsr.eui.eu.
Crew, M. A., & Kleindorfer, P. R. (1996). Prices caps and revenue caps: Incentives and disincentives for efficiency. In M. A. Crew (Ed.), *Pricing and regulatory innovations under increasing competition* (pp. 39–52). Boston: Kluwer Academic.
Economic Consulting Associates Ltd. (2018). Methodologies and parameters used to determine the allowed or target revenue of gas transmission system operators (TSOs). https://www.acer.europa.eu.
ENTSOG. (2019). ENTSOG transparency platform. https://transparency.entsog.eu.
European Commission. (2017a). Commission Regulation (EU) 2017/459 of 16 March 2017 establishing a network code on capacity allocation mechanisms in gas transmission systems and repealing Regulation (EU) No 984/2013. OJ L 72/1-28.
European Commission. (2017b). Commission Regulation (EU) 2017/460 of 16 March 2017 establishing a network code on harmonised transmission tariff structures for gas. OJ L72/29-56.
European Parliament and Council of the European Union. (2009a). Regulation (EC) No 715/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the natural gas transmission networks and repealing Regulation (EC) No 1775/2005. OJ L 211/36-54.
European Parliament and Council of the European Union. (2009b). Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC. OJ L 211/94-136.
EY and REKK. (2018). Quo vadis EU gas market regulatory framework—Study on a Gas Market Design for Europe. Study for the European Commission. https://ec.europa.eu/energy/en/studies/.
Giannakis, D., Jamasb, T., & Pollitt, M. (2005). Benchmarking and incentive regulation of quality of service: an application to the UK electricity distribution networks. *Energy Policy, 33*(17), 2256–2271.
Hecking, H. (2015). Rethinking entry-exit: two new tariff models to foster Competition and Security of Supply in the EU Gas Market. ewi Energy Research & Scenarios gGmbH. https://www.ewi.uni-koeln.de.

Jamasb, T., & Pollitt, M. (2003). International benchmarking and regulation: An application to European electricity distribution utilities. *Energy Policy, 31*(15), 1609–1622.
Keller, J. T., Kuper, G. H., & Mulder, M. (2019). Mergers of Germany's natural gas market areas: Is transmission capacity booked efficiently? *Utilities Policy, 56,* 104–119.
Laffont, J., & Tirole, J. (1996). Creating competition through interconnection: Theory and practice. *Journal of Regulatory Economics, 10*(3), 227–256.
Mulder, M. (2012). Financeability of investments and allocation of costs: An assessment of the incentive regulation of the dutch high-voltage network. *Competition and Regulation in Network Industries, 13*(2), 160–186.
Sibley, D. (1989). Asymmetric information, incentives and price-cap regulation. *RAND Journal of Economics, 20*(3), 392–404.
Stoft, S. (1995). Revenue caps vs. price caps: Implications for DSM. Chapter 4 of LBL Report #37577. 4-1-C-38.
Ströbele, W., Pfaffenberger, W., & Heuterkes, M. (2012). *Energiewirtschaft: Einführung in Theorie und Politik* (3rd ed.). Munich: Oldenbourg Verlag.
Vazquez, M., Hallack, M., & Glachant, J. (2012). Designing the European Gas Market: More liquid and less natural? *Economics of Energy and Environmental Policy, 1*(3), 25–38.
Vogelsang, I. (2002). Incentive regulation and competition in public utility markets: A 20-year perspective. *Journal of Regulatory Economics, 22*(1), 5–27.
Vogelsang, I., & Cave, M. (2019). Pricing under the new regulatory framework provided by Part 6 of the Telecommunications Act. https://comcom.govt.nz.